

# MOBILE OFFSHORE BASE

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## ABSTRACT

**A Mobile Offshore Base (MOB) provides a forward-deployable logistics facility capable of conducting flight, maintenance, supply and other military support operations. A general set of mission requirements, driven by fixed wing cargo aircraft operations, results in MOB concepts around 1,500 m (5,000 ft) in length. Both the specialized functions and long length of a MOB platform make it unique compared to any floating structure ever built. This paper describes the research and development efforts underway along with alternative structural concepts currently under consideration to meet the technical challenges.**

**Key Words:** Megastructure, floating airfield, semisubmersible, platform, mobility, module connectors, logistics

## INTRODUCTION

The Office of Naval Research (ONR) is conducting a Science and Technology (S&T) Program to assess technical feasibility for Mobile Offshore Bases (MOB) using commercial design procedures and standards. The MOB platform being sought is unique compared to any floating structure ever built. While the U.S. Department of Defense has not officially established mission requirements for a MOB, many of the proposed notional needs are unprecedented:

- Conventional take-off and landing of fixed-wing cargo aircraft at sea
- High-throughput cargo transfer to ships and landing craft in open oceans
- Large volume of climate-controlled storage for a variety of military cargo
- Selective accessibility to all cargo for retrieval, refurbishment, or repair
- Occupancy by a large group of military personnel even during storms
- Survivability in severe environments including hurricanes and typhoons
- Economical long-life maintainability and repairability
- Long-term station-keeping in deep water sites anywhere in the world

The primary objective of the ONR S&T Program is to resolve fundamental uncertainties regarding MOB feasibility and estimate cost. This is not an acquisition program. A collaborative team of industry participants, along

with Government support, is working in four critical technology areas:

- Mission Requirements and Performance Measures
- Standards and Criteria
- Design Tools
- Alternative Concepts

This paper gives a brief summary of each technology area but primarily emphasizes system platform concepts. A better description of the overall program, including details of the program plan, is available at the World Wide Web address (<http://www.mob.mfesc.navy.mil>).

## Mission Requirements and Performance Measures

This effort defines the functional requirements for potential MOB missions, and develops a rational procedure for evaluating alternative MOB concepts on the basis of functional performance, operational availability and system cost. These will allow rigorous evaluation of how well a specific MOB platform concept satisfies the mission requirements at a particular site. In addition, the effort will provide evaluation tools for conducting cost/benefit trade-off studies for unique sets of functional requirements. Providing a common design basis for design of alternative concepts, the list of functional requirements currently includes the following notional criteria:

- **Physical Size:** The overall dimensions would have to be at least 1,500 m (5,000 ft) long and 150 m (500 ft) wide in order to accommodate McDonnell Douglas C-17 Globemaster cargo aircraft on deck.
- **Structural Modularity:** Depending on temporal requirements, the MOB may operate as a single monohull (capable of transferring cargo by helicopter or ocean vessel) or as a connected set of modules (capable of landing fixed wing aircraft).
- **Logistics Capability:** The MOB should contain up to 800,000 m<sup>3</sup> (9 million ft<sup>3</sup>) of environmentally controlled dry cargo storage and up to 40,000 m<sup>3</sup> (10 million gallons) of fuel storage.
- **Operability:** The MOB may need to house up to 3,000 troops, support aircraft operations in winds up to the C-17's normal ability to land or takeoff, and facilitate transfer of military cargo to water craft in seas exceeding their normal berthing limits.
- **Survivability:** Since it may not outrun a storm, the MOB must

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survive in the most severe of environmental conditions, including hurricanes and typhoons.

- **Maintainability:** For minimal life cycle cost, the MOB may need to operate for 40 years between major overhauls.
- **Station-Keeping & Mobility:** Depending on changing mission needs, the separable modules may be stationed individually in various locations around the world. To be brought rapidly together for fixed wing aircraft operations, each module may need to transit at speeds of 10 knots or more.

## Standards and Criteria

As the exclusive classification society for U. S. Government vessels and marine equipment, the American Bureau of Shipping (ABS) is leading the development of a MOB Classification Guide. The approach used is to modify existing commercial standards to the unique characteristics of the MOB platform and military mission. Addressing survival and fatigue structural responses, stability, and stationkeeping, this Guide will serve as the basis for certifying structural adequacy and safety. The emphasis will be on platform integrity, as defined by a variety of fatigue, operating, and survival scenarios, at arbitrary worldwide sites. The Guide will also define realistic environmental descriptors for survival, operational, and fatigue analyses, including wind, waves, and current. Directional, temporal, spatial, and joint probabilities will be included based on a critical examination of known physical ocean processes (e.g., hurricanes).

## Design Tools

Due to the potentially large structural loads generated by this very large floating structure, current hydrodynamic and structural analysis tools cannot be used with full confidence in designing MOB. This program is advancing hydroelastic models as well as developing an interface between hydroelastic and structural models. Hydroelasticity is important to MOB in that it provides reductions in structural loads due to flexibility of the structure. Through a comprehensive wave tank experiment on hydroelastic behavior of floating structures, the program will also generate unique hydroelastic data for validation of these models and interfaces. The program will specifically perform the following tasks:

- Evaluate the existing hydrodynamic and hydroelastic models for simulating the dynamic responses, including second-order wave drift forces on the platform and relative motions and interactions between a cargo vessel(s) and the MOB.
- Develop a new numerical hydroelasticity model by incorporating higher-order diffraction elements into an existing hydroelastic model to make it numerically feasible to model very large coupled platforms such as MOB.
- Develop a semi-analytical hydroelastic model to complement the new numerical model.
- Develop a load generator to convert hydrodynamic excitation and reaction panel pressure forces, along with a stochastic description of a random sea, into pressures over a comparable surface of a finite element structural model.
- Conduct a comprehensive experiment of hydroelastic behavior of floating structures to validate the various analysis models.

## Alternative Concepts

Since early in this century, several types of concepts have been proposed for Very Large Floating Structures (VLFS) as reviewed by Ochi and Vuolo (1971) and Yoshida (1996). A MOB has possible military roles that make it both large and unique compared to traditional offshore

platforms and most concepts for VLFS (McAllister 1996). To gauge the true meaning of this size and uniqueness, the program is investigating alternative concepts for both the overall system platform and its subsystem component. Pushing the state-of-the-art, these preliminary or “point designs” provide the following science and technology benefits:

- Develop concepts to identify inherent strengths and weaknesses
- Assess adequacy of chosen engineering requirements
- Identify parts of the classification process that need modification or extension
- Characterize deficiencies in existing analysis tools and validation data
- Identify technology gaps needed to properly design, build and operate a MOB

Subsystem concepts being developed to address key technology gaps are:

- Inter-module connectors
- Alternative marine materials
- Station-keeping subsystem
- Response mitigation methods
- Construction/repair methods
- Open sea cargo transfer techniques

## SYSTEM PLATFORM CONCEPTS

MOB would likely not be a monolithic, full-length, full-depth hull. Because of the high bending stiffness in the cross-section of such a monolithic hull, the structural forces along the keel that result from simple hog and sag structural modes would generally be much larger than desired. One can reduce these forces by allowing the structure to comply with the sea surface. The obvious way to comply to the sea surface is to divide the hull into modules and allow some relative motion between modules. In theory, this compliance to the sea surface reduces the overall structural loads, but too much relative motion between the modules may result in a flight deck that is not adequately straight, continuous and level.

Dealing uniquely with the issue of structural compliancy and how to balance structural forces with motion, four major offshore contractors are currently each developing a system platform concept:

- Hinged Semisubmersible Modules (McDermott International, Inc.)
- Semisubmersible Modules with Flexible Bridges (Kvaerner Maritime — Seabase Inc.)
- Independent Semisubmersible Modules (Bechtel National Inc.)
- Concrete/Steel Semisubmersible Modules (Aker Norwegian Contractors a.s.)

The key difference between each of these system platform concepts is the method used to connect several smaller modules into a structure of sufficient length for MOB. Each of these contractors has chosen a semisubmersible hull as the basis for their modules because of the many advantages it offers. One key advantage is that a semisubmersible hull operates at two different drafts, a high draft that minimizes motions on site and a low draft that minimizes drag in transit. The semisubmersible hull is fairly unique in maintaining good overturning stability at both of these drafts. A semisubmersible hull has a deck supported by tubular columns, connected at their base by two parallel very large (bow to stern) pontoons.

A typical semisubmersible MOB module would displace at least four times as much water as a Nimitz-class carrier. While positioned on site, one ballasts down the semisubmersible hull to minimize water plane area and to place the pontoons well below the region of highest wave energy. Compared to its large size, the semisubmersible hull develops relatively small overall environmental forces and related motions in the high draft condition.

A typical semisubmersible MOB pontoon would be about the size of a typical crude oil tanker. While transiting from one site to another, one ballasts up the semisubmersible hull to bring most of the hull above water and to ride on the ship-shape pontoons. Compared to its large size, the semisubmersible hull develops relatively small transit drag in the low draft condition.

- **Hinged Semisubmersible Modules**

This concept consists of five rectangular semisubmersible steel modules, each 300m (985 ft) long, as shown in Fig. 1. Hinge-type compliant connectors link the individual modules and allow freedom of motion (primarily in pitch) between adjacent modules. A dynamic positioning system provides absolute positioning of the overall MOB and relative positioning of each module during connection.

Shown just as simple hinges in Fig. 1, the hinge-type connectors actually utilize an arrangement of quick-release pins and large collapsible rubber cones. The pins reduce the vertical bending forces of the hog and sag structural modes by allowing freedom of motion in pitch. The collapsible cones allow compliance in some of the other degrees of freedom, particularly in yaw. At low force levels, the cones are stiff and provide for a straight runway. At high force levels, the cones collapse, provide reduced stiffness to yaw motion, and thus, reduce related resistance forces.

The response of any MOB platform in operational and survival sea states is a function of hydrodynamic form and connector design. Oblique waves can induce large horizontal bending and torsional forces. Hydrodynamic and structural analyses show that, under particular circumstances, connector loads can increase with increasing compliance in the connector (Wu & Mills, 1996). A time-domain approach to the analyses is necessary to represent the nonlinear structural behavior of the compliant connectors. As such, validation against experimental data is necessary.

The concept may require disconnection into separate modules to survive in high seastates. Accordingly, this connector is designed for

quick connection and disconnection of the modules, even in a fairly rough sea environment. Fixed-wing aircraft must be able to taxi over the discrete angular changes in the runway that can result from pitch rotation in these connectors. Because of high loads in the moving connectors, material degradation or mechanical fatigue may be a critical issue for this concept.

- **Semisubmersible Modules with Flexible Bridges**

This system platform concept consists of three rectangular semisubmersible steel modules, each about 280m (920 ft) long, as shown in Figs. 2a and 2b. Flexible truss bridges, each about 435m (1425 ft) long, connect the modules. The weight of the flexible bridge rests on adjacent semisubmersible modules using a keyed joint. The flexible bridges help maintain a continuous flight deck while still providing the desired compliance to the sea surface. Designed as minimal structure with no cargo storage capability, each flexible bridge is a semisubmersible structure that can float into position prior to connection. A dynamic positioning system on board each semisubmersible provides relative positioning during connection and absolute positioning of the overall MOB.

The long length and inherent flexibility of the bridges allow the semisubmersible modules to move relative to one another without concentration of the forces. Providing distributed compliance, the flexible bridge maintains a runway that is continuous in both translational and rotational degrees of freedom. The concept may require disconnection of the modules to survive in high storm conditions. The weight of the flexible bridge resting upon the semisubmersible modules raises the issue of how to achieve a fail safe release of this inter-module connector. There is less cargo storage capacity than other system platform concepts because open-truss bridges cannot generally store cargo. Because of high flexibility demand in the bridges, fatigue life of the steel tubulars may be a critical issue for this concept.

- **Independent Semisubmersible Modules**

This concept consists of three rectangular semisubmersible steel modules, each about 488m (1,600 ft) long, as shown in Fig. 3. Dynamic positioning maintains overall orientation and close relative position of modules. An easily raised drawbridge spans the nominal 45m (150 ft) gap between modules and creates a continuous airplane runway. Although the individual modules are functionally connected with drawbridges, no



Fig. 1 Hinged Semisubmersible Modules

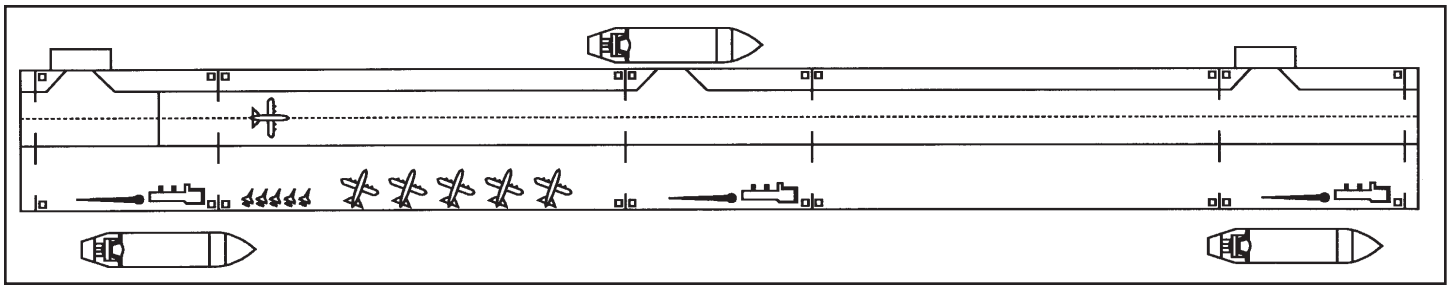


Fig. 2a Semisubmersible Modules with Flexible Bridges - Plain View

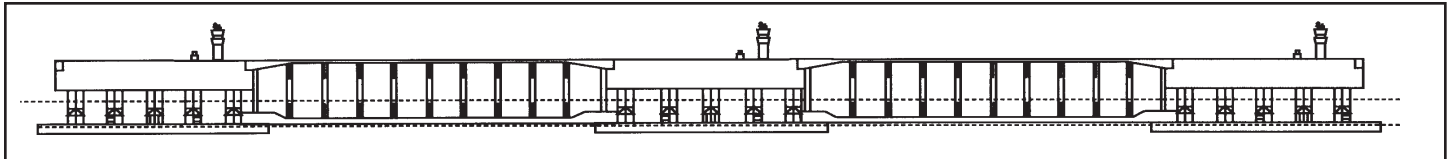


Fig. 2b Semisubmersible Modules with Flexible Bridges - Side View

structural connection exists between modules. The lack of a structural connection between modules ensures compliance to the sea surface.

One disconnects this concept into separate modules by simply raising the drawbridge and powering the modules apart. Each module may then operate independently as a smaller MOB whenever fixed-wing air operations are not required. The large length of each module is much greater than the current state-of-art for semisubmersible construction. However, there is a definite benefit to this long length; it results in little motion from waves.

The concept requires a new type of Dynamic Positioning System (DPS). The traditional DPS for the offshore petroleum industry is designed to position an ocean platform precisely over an absolute location in the ocean, namely directly over the drill hole. A MOB requires no such absolute positioning. A MOB could drift slowly around with no adverse effect on operations. Perhaps it could even take advantage of prevailing currents or winds to move from one strategic sea to another.

Rather than control of *absolute* position, a MOB requires precise control of position and alignment of one semisubmersible module *relative* to the others. For the drawbridge to function properly, the MOB DPS must hold modules in close relative alignment (relative watch circle of 20 feet) to one another. This may require a special multiple-module, relative-

position dynamic positioning system with feed forward environmental sensing. The feasibility of the Independent Semisubmersible Module MOB concept depends on the performance of this new type of dynamic positioning system. Its efficiency determines overall fuel costs.

Each module needs several rotating propulsion units, each with a thruster power that is generally beyond the state-of-practice. Modern DPS are triply redundant, meaning there are three fully independent sets of hardware (computers, wiring, sensors, and propellers). Consisting of up to three separable modules, the Independent Semisubmersible Module MOB could have up to 9 redundant sets of hardware to ensure the same standard of system reliability. Because of these unique relative-motion multi-body requirements, the critical issue for this concept may be dynamic positioning control and its reliability.

#### • Concrete/Steel Semisubmersible Modules

This concept consists of rectangular semisubmersible modules, each 380m (1,250 ft) long, as shown in Fig. 4. Each module has a steel deck and a concrete hull. The necessary cross-bracing between pontoons of the hull are steel. A combination of innovative elastomer bearings and post-tensioned cables connect modules.

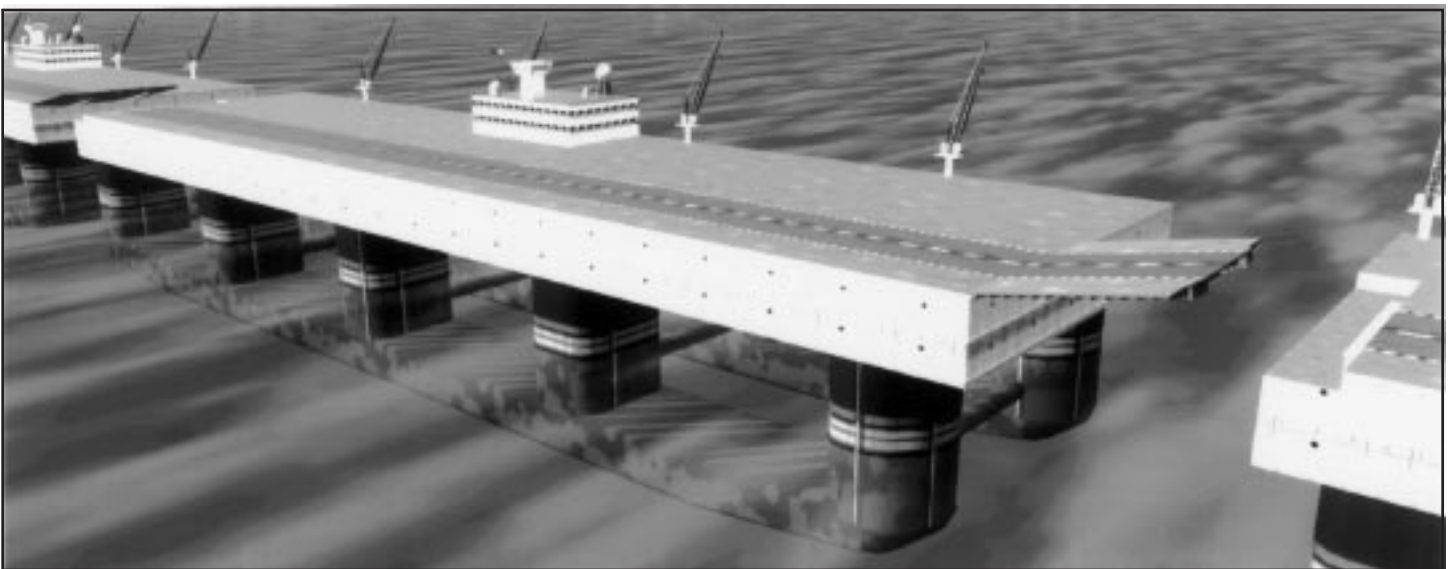


Fig. 3 Independent Semisubmersible Modules

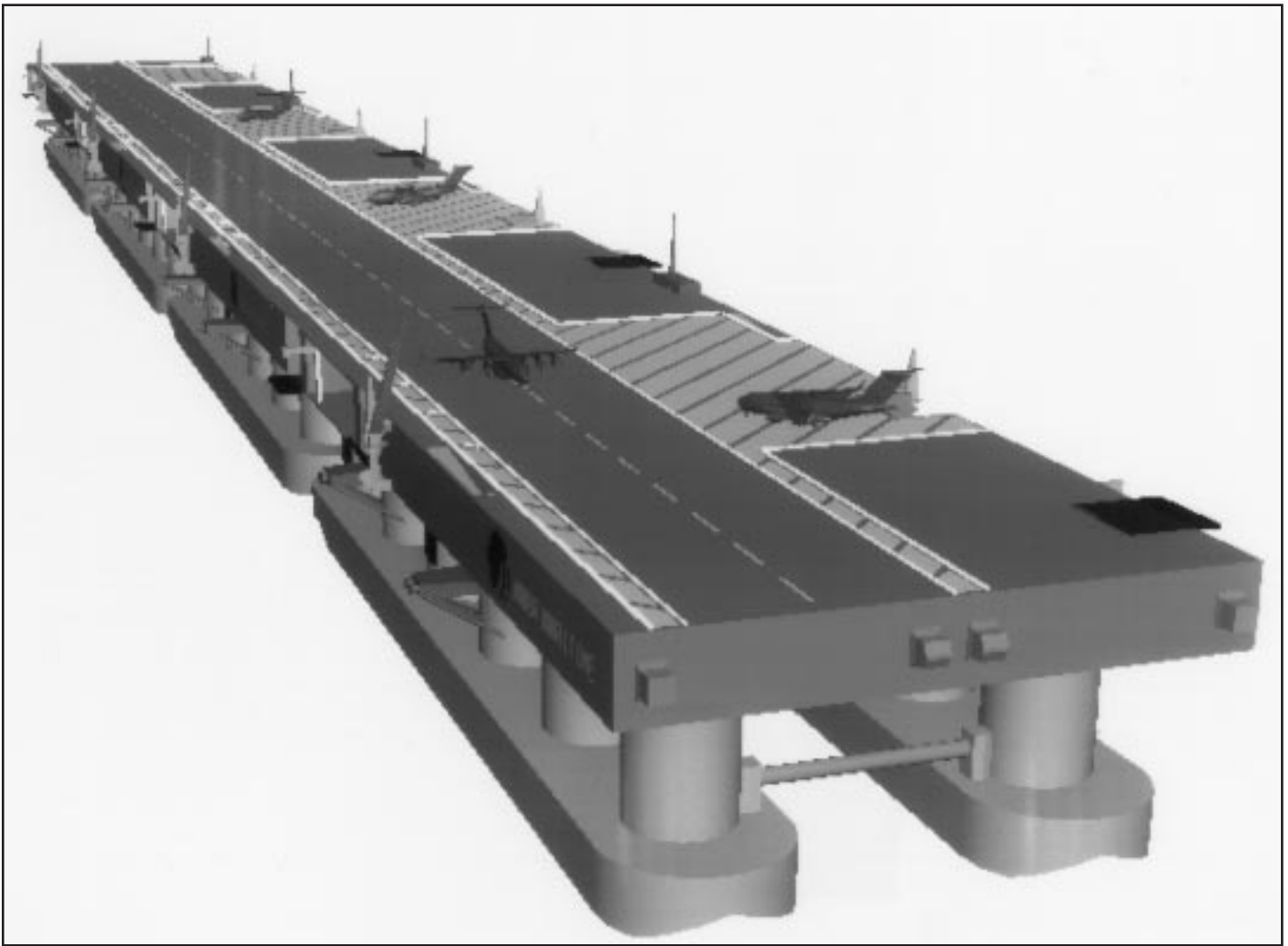


Fig. 4 Concrete/Steel Semisubmersible Modules

The focus of this effort is not necessarily to develop a unique system platform concept but rather to identify and describe the suitability and limitations of reinforced and prestressed concrete as an alternative material. Issues include structural flexibility of concrete, methods of construction, and durability of marine concrete. Concrete may be preferable to steel when issues such as fatigue life, blast resistance, and ease of in-situ construction/repair are considered. Choosing concrete over steel may result in a lower life cycle cost.

This cost advantage for concrete may be a function of overall MOB size. A key to this advantage is the innovative ability to form the structure on the water using a floating slip-forming construction scenario. This allows construction of the MOB to any length and breadth without consideration given to the confining size of even the world's largest dry docks. Since a concrete structure would weigh more than an equivalent steel structure, a hybrid concrete/steel structure offers a compromise to this weight difference. The lighter steel deck versus the heavier concrete deck also ensures a more stable MOB structure by lowering the center of gravity. Because of the heavy unit weight of concrete, cargo capacity may be critical issues for this concept.

## CONCLUSION

The primary objective of the ONR S&T Program is to establish technical feasibility and cost for a Mobile Offshore Base (MOB).

Resolution of the fundamental uncertainty regarding feasibility requires advancements in design tools, standards, criteria, system and component concepts, and means for assessing the adequacy of any system concept to satisfy mission requirements. The products of this collaborative effort, namely the *ABS Classification Guide* and the validated analyses tools, will give industry the capability to design and build a MOB. It will also give the Department of Defense the means to evaluate the overall technical feasibility and economical affordability of any of the proposed concepts for a MOB.

This paper presented four specific system platform concepts. Each addresses the current MOB mission requirements in a different way. Each concept has specific technical merits, some noted in this paper. When final results from each current concept development are available, the general feasibility of a MOB will become quantifiable. Since the mission requirements of MOB are subject to change, it is important to maintain flexibility in the program and pursue technology developments which might make many concepts feasible. Accordingly, this S&T Program will not select a preferable concept and will continue to consider new innovative approaches to a MOB.

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